Interface Reconstruction in Multi-fluid Flow Simulations

Rao V. Garimella, rao@lanl.gov
Vadim Dyadechko, dyadechko@lanl.gov
Blair K. Swartz, bks@lanl.gov
Mikhail J. Shaskov, shashkov@lanl.gov

Hydrodynamic simulations of flows involving multiple fluids and/or multiple phases are an important research area with many applications such as droplet deposition, sandwich molding processes, underwater explosions, mold-filling in casting, simulations of micro-jetting devices, etc.

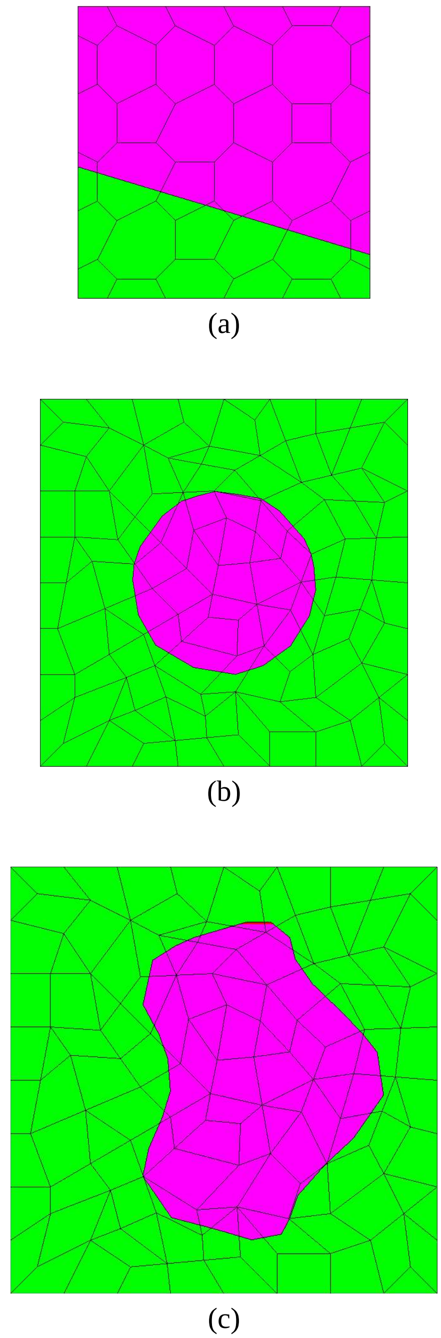
An important feature of such flows is the interface between the materials (fluids and their phases), and it is often crucial to follow such interfaces during the simulation. Lagrangian simulations (where the mesh nodes move with the flow) automatically maintain interfaces, but cannot handle large deformations and topology changes of these interfaces. On the other hand, Eulerian simulations (where the mesh nodes are stationary) must incorporate special procedures to keep track of the interfaces in the flow.

We have developed an advanced method for recovering a piecewise linear approximation of material interfaces in flow simulations given the volume fractions of materials in the cells of an unstructured mesh. The method incorporates several new techniques designed to make the reconstruction method more accurate (generally 2nd order), rapid and robust. These include the careful selection and use of interface neighbor cells, and a topological consistency checking and repair algorithm for the interface that is designed to minimize fragmentation of the material regions being reconstructed. The volume of the materials is conserved exactly in the method.

The main steps of the procedure are:

1. *Interface Estimation:* A rough estimate of the interface is constructed using the volume fraction data specified on cells. The interface is represented by one line segment per cell.

2. *Interface Smoothing:* Interface segments are



(a)

(b)

(c)

Multi-segmented interface reconstruction tests on unstructured meshes: (a) Straight line interface (b) Circular interface (c) Complex Interface.

adjusted taking into account other interface segments in the neighborhood so that the resulting interface is as smooth as possible. For example, straight line interfaces are typically recovered by this interface smoothing step.

3. *Interface Topology Repair:* The interface segments are adjusted so that they satisfy essential consistency requirements. The result of this is that the reconstructed material regions are continuous and do not have holes or fragments as far as possible.

4. *Constrained Interface Smoothing:* Alterations made to the interface in the repair step are smoothed, with the constraint that the topological consistency of vertices cannot be destroyed.

5. *Interface Subdivision and Matching:* The interface segment in each cell is subdivided into two. The two segments in the cell are then adjusted so that their slopes match the slopes of the appropriate interface segments in neighboring cells and the material volumes in the cell are conserved.

The procedure recovers complex interfaces more accurately than other interface reconstruction procedures, particularly exhibiting reduced fragmentation in the single vortex test [1, 2].

References

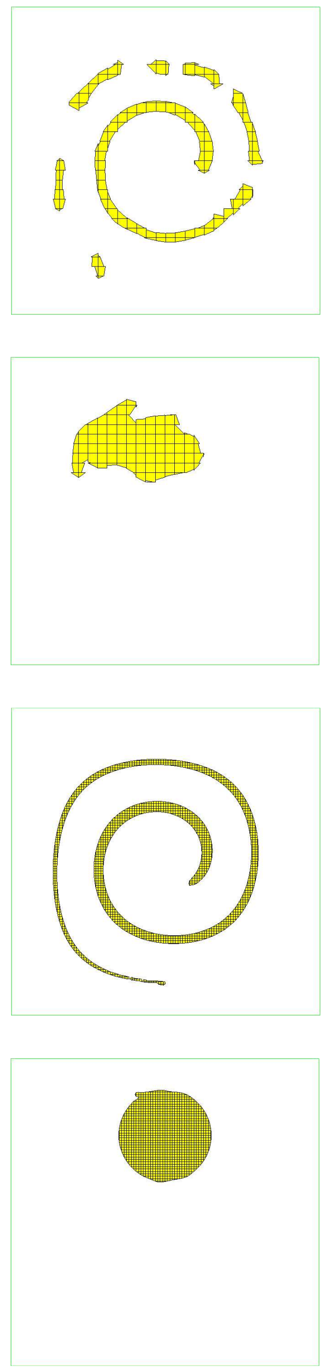
[1] W. J. Rider and D. B. Kothe. Reconstructing volume tracking. *Journal of Computational Physics*, 141:112–152, 1998.

[2] D. Enright, R. Fedkiw, J. Ferziger, and I. Mitchell. A hybrid particle level set method for improved interface capturing. *Journal of Computational Physics*, 183:83–116, 2002.

Acknowledgements

Funded by the Department of Energy under contracts W-7405-ENG-36 and the DOE Office of Science's Advanced Scientific Computing Research (ASCR) program in Applied Mathematical Sciences. The authors acknowledge the support from the Advanced Simulation and Computing (ASC) Program.

Los Alamos Report LA-UR-05-2936.



(a) (b) (c) (d)

Results of a time reversed single vortex simulation for: (a) 32x32 grid at t=4 (maximal stretch) (b) 32x32 grid at t=8 (fully reversed flow) (c) 128x128 grid at t=4 (d) 128x128 grid at t=8